(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 235 993 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
30.08.2023 Bulletin 2023/35

(21) Application number: **23168939.9**

(22) Date of filing: **09.09.2016**

(51) International Patent Classification (IPC):
H02G 15/18 *(2006.01)* ***H02G 15/188*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
H01B 3/28; H01B 3/46; H01B 19/00; H02G 15/1833; H02G 15/188

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **17.09.2015 US 201514856850**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
20191691.3 / 3 758 178
16767474.6 / 3 350 896

(71) Applicants:
- **Tyco Electronics (Shanghai) Co. Ltd.**
  Shanghai (CN)
- **TE Connectivity Corporation**
  Berwyn, PA 19312 (US)

(72) Inventors:
- **Yaworski, Harry**
  Cary NC, 27518 (US)
- **Tse, Alan**
  Apex NC, 27539 (US)
- **Yang, Lizhang**
  Shanghai (CN)

(74) Representative: **Scott, Fiona Penelope Elaine et al**
Baron Warren Redfern
1000 Great West Road
Brentford TW8 9DW (GB)

Remarks:
This application was filed on 21.04.2023 as a divisional application to the application mentioned under INID code 62.

(54) **COVER ASSEMBLIES AND METHODS FOR COVERING ELECTRICAL CABLES AND CONNECTIONS**

(57) A pre-expanded cover assembly for protecting a cable splice connection including a cable, the cable including an electrical conductor surrounded by a cable insulation layer, includes a splice body assembly and a removable holdout. The splice body assembly includes a tubular, cold-shrinkable, electrically insulative, elastomeric splice body having an interior surface defining an interior passage. The splice body assembly further includes a tubular layer of a conformable medium pre-mounted on the interior surface of the splice body. The conformable medium is a flowable material having a high electrical permittivity. The splice body assembly is mounted on the holdout such that the holdout maintains the splice body in an elastically radially expanded state, and the holdout is selectively removable from the splice body to permit the splice body to elastically radially contract. The layer of the conformable medium is positioned and configured such that, when the pre-expanded cover assembly is positioned adjacent the cable splice connection, the holdout is removed from the splice body, and the splice body elastically radially contracts onto the cable splice connection, the layer of the conformable medium will be radially interposed between and engage each of the interior surface of the splice body and an opposing interface surface of the cable insulation.

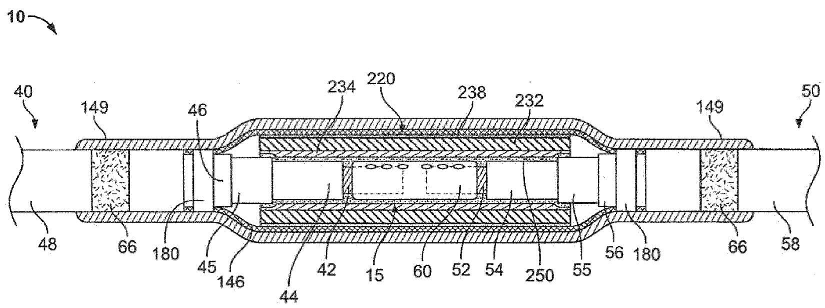

Fig. 7

EP 4 235 993 A1

Description

Field of the Invention

[0001] The present invention relates to electrical cables and connections and, more particularly, to protective covers for electrical cables and electrical connections.

Background of the Invention

[0002] In the electrical utilities industry, maintaining cable integrity may be critical. A loss of cable integrity, for example, a short circuit in a high voltage cable, may result in a crippling power outage or, even worse, a loss of life. One everyday task that may pose a great threat to cable integrity is the formation of electrical connections.

[0003] When electrical connections are formed, a bare metal surface may be exposed such as a splice connector. These bare metal surfaces may be particularly hazardous when formed in the field where they are exposed to the environment. This environment may include rocks and other sharp objects as well as moisture when the connection is to be buried under ground and rainfall when the connection is to be suspended in the air. Thus, there is a need to protect such electrical connections from the environment.

Summary of the Invention

[0004] According to embodiments of the invention, a pre-expanded cover assembly for protecting a cable splice connection including a cable, the cable including an electrical conductor surrounded by a cable insulation layer, includes a splice body assembly and a removable holdout. The splice body assembly includes a tubular, cold-shrinkable, electrically insulative, elastomeric splice body having an interior surface defining an interior passage. The splice body assembly further includes a tubular layer of a conformable medium pre-mounted on the interior surface of the splice body. The conformable medium is a flowable material having a high electrical permittivity. The splice body assembly is mounted on the holdout such that the holdout maintains the splice body in an elastically radially expanded state, and the holdout is selectively removable from the splice body to permit the splice body to elastically radially contract. The layer of the conformable medium is positioned and configured such that, when the pre-expanded cover assembly is positioned adjacent the cable splice connection, the holdout is removed from the splice body, and the splice body elastically radially contracts onto the cable splice connection, the layer of the conformable medium will be radially interposed between and engage each of the interior surface of the splice body and an opposing interface surface of the cable insulation.

[0005] According to method embodiments of the invention, a method of manufacturing a pre-expanded cover assembly for protecting a cable splice connection including a cable, the cable including an electrical conductor surrounded by a cable insulation layer, includes: mounting a tubular layer of a conformable medium on a removable holdout, wherein the conformable medium is a flowable material having a high electrical permittivity; and thereafter mounting a tubular, cold-shrinkable, electrically insulative, elastomeric splice body on the holdout over the conformable medium such that the holdout maintains the splice body in an elastically radially expanded state and an interior surface of the splice body defines an interior passage and engages the conformable medium. The holdout is selectively removable from the splice body to permit the splice body to elastically radially contract. The layer of the conformable medium is positioned and configured such that, when the pre-expanded cover assembly is positioned adjacent the cable splice connection, the holdout is removed from the splice body, and the splice body elastically radially contracts onto the cable splice connection, the layer of the conformable medium will be radially interposed between and engage each of the interior surface of the splice body and an opposing interface surface of the cable insulation.

[0006] According to method embodiments of the invention, a method for protecting a cable splice connection including a cable, the cable including an electrical conductor surrounded by a cable insulation layer, includes providing a pre-expanded cover assembly including a splice body assembly and a removable holdout. The splice body assembly includes a tubular, cold-shrinkable, electrically insulative, elastomeric splice body having an interior surface defining an interior passage. The splice body assembly further includes a tubular layer of a conformable medium pre-mounted on the interior surface of the splice body, wherein the conformable medium is a flowable material having a high electrical permittivity. The splice body assembly is mounted on the holdout such that the holdout maintains the splice body in an elastically radially expanded state, and the holdout is selectively removable from the splice body to permit the splice body to elastically radially contract. The method further includes mounting the splice body assembly on the splice connection, including: positioning the pre-expanded splice body assembly adjacent the cable splice connection; and removing the holdout from the splice body assembly to permit the splice body to elastically radially contract onto the cable splice connection such that the layer of the conformable medium is radially interposed between and engages each of the interior surface of the splice body and an opposing interface surface of the cable insulation layer.

[0007] Further features, advantages and details of the present invention will be appreciated by those of ordinary skill in the art from a reading of the figures and the detailed description of the preferred embodiments that follow, such description being merely illustrative of the present invention.

[0008] Embodiments of the invention include a pre-expanded cover assembly for protecting a cable splice connection including a cable, the cable including an electrical conductor surrounded by a cable insulation layer, the pre-expanded cover assembly comprising: a splice body assembly including: a tubular, cold-shrinkable, electrically insulative, elastomeric splice body having an interior surface defining an interior passage; and a tubular layer of a conformable medium pre-mounted on the interior surface of the splice body, wherein the conformable medium is a flowable material having a high electrical permittivity; and a removable holdout, wherein the splice body assembly is mounted on the holdout such that the holdout maintains the splice body in an elastically radially expanded state, and the holdout is selectively removable from the splice body to permit the splice body to elastically radially contract; wherein the layer of the conformable medium is positioned and configured such that, when the pre-expanded cover assembly is positioned adjacent the cable splice connection, the holdout is removed from the splice body, and the splice body elastically radially contracts onto the cable splice connection, the layer of the conformable medium will be radially interposed between and engage each of the interior surface of the splice body and an opposing interface surface of the cable insulation.

[0009] The splice body suitably includes a tubular primary insulation layer formed of extruded silicone or ethylene propylene diene monomer (EPDM) rubber.

[0010] The splice body of the pre-expanded cover assembly may further include a semiconductor layer covering an outer surface of the primary insulation layer.

[0011] The conformable medium provided in the pre-expanded cover assembly is is a mastic. The mastic has a dielectric constant of at least about 10. The mastic may have a dielectric constant in the range of from about 15 to 25.

[0012] In the pre-expanded cover assembly of the invention the splice body includes a tubular primary insulation layer formed of an electrically insulating elastomer, the primary insulation layer extending from a first axial end to an opposed second axial end; the interior passage terminates at the first and second axial ends; the tubular layer of mastic extends continuously from the first axial end to the second axial end.

[0013] The mastic of the pre-expanded cover assembly is a silicone rubber-based mastic that has a plasticity number in the range of from about 150 to 650 according to ISO 7323 and is deformable at all temperatures in the range of -20C to 50C. The mastic has a dielectric strength in the range of from about 250 Volts/mil to 700 Volts/mil.

[0014] The holdout of the pre-expanded cover assembly includes a tubular holdout formed by a helically wound strip, and the holdout is configured to be removed from the splice body assembly by pulling the strip.

[0015] The splice body of the pre-expanded cover assembly includes a tubular primary insulation layer formed of an electrically insulating elastomer, the primary insulation layer extending from a first axial end to an opposed second axial end; an interior passage terminating at the first and second axial ends; the splice body further includes an integral, tubular inner elastomeric layer extending continuously from the first axial end to the second axial end and radially interposed between the primary insulation layer and the conformable medium; and the inner elastomeric layer is formed of an elastomer having high permittivity.

[0016] The pre-expanded cover assembly further includes a tubular Faraday cage sleeve mounted on the holdout and radially interposed between the holdout and the conformable medium.

[0017] The pre-expanded cover assembly further includes a conformable, flowable electrically insulating medium pre-mounted on the interior surface of the splice body.

[0018] A method of manufacturing a pre-expanded cover assembly for protecting a cable splice connection including a cable, the cable including an electrical conductor surrounded by a cable insulation layer is also provided, the method comprising: mounting a tubular layer of a conformable medium on a removable holdout, wherein the conformable medium is a flowable material having a high electrical permittivity; and thereafter mounting a tubular, cold-shrinkable, electrically insulative, elastomeric splice body on the holdout over the conformable medium such that the holdout maintains the splice body in an elastically radially expanded state and an interior surface of the splice body defines an interior passage and engages the conformable medium; wherein the holdout is selectively removable from the splice body to permit the splice body to elastically radially contract; and wherein the layer of the conformable medium is positioned and configured such that, when the pre-expanded cover assembly is positioned adjacent the cable splice connection, the holdout is removed from the splice body, and the splice body elastically radially contracts onto the cable splice connection, the layer of the conformable medium will be radially interposed between and engage each of the interior surface of the splice body and an opposing interface surface of the cable insulation.

[0019] The method further includes the step of forming the splice body, wherein: the splice body includes a tubular primary insulation layer formed of extruded silicone or ethylene propylene diene monomer (EPDM) rubber; and forming the splice body includes extruding a tube of EPDM rubber and cutting the tube of EPDM rubber to form the primary insulation layer.

[0020] The splice body used in the method further includes a semiconductor layer covering an outer surface of the primary insulation layer; and forming the splice body includes co-extruding the tube of EPDM rubber and a tube of semiconductive elastomer to form a combined tube, and cutting the combined tube to form the primary insulation layer and the semiconductor layer.

[0021] The splice body used in the method further includes a semiconductor layer covering an outer surface of the primary insulation layer; and forming the splice body includes applying a semiconductor coating to an outer surface of the tube of EPDM rubber by painting, spraying or dipping to form the semiconductor layer.

[0022] The splice body used in the method includes a tubular primary insulation layer formed of an electrically insulating elastomer, the primary insulation layer extending from a first axial end to an opposed second axial end; the interior passage terminates at the first and second axial ends; the splice body further includes an integral, tubular inner elastomeric layer extending continuously from the first axial end to the second axial end and radially interposed between the primary insulation layer and the conformable medium; the inner elastomeric layer is formed of an elastomer having high permittivity; and the method includes forming the splice body by co-extruding the primary insulation layer and the inner elastomeric layer.

[0023] The method further includes mounting a tubular Faraday cage sleeve on the holdout radially between the holdout and the conformable medium.

[0024] Amethod for protecting a cable splice connection including a cable, the cable including an electrical conductor surrounded by a cable insulation layer, the method comprising: providing a pre-expanded cover assembly comprising: a splice body assembly including: a tubular, cold-shrinkable, electrically insulative, elastomeric splice body having an interior surface defining an interior passage; and a tubular layer of a conformable medium pre-mounted on the interior surface of the splice body, wherein the conformable medium is a flowable material having a high electrical permittivity; and a removable holdout, wherein the splice body assembly is mounted on the holdout such that the holdout maintains the splice body in an elastically radially expanded state, and the holdout is selectively removable from the splice body to permit the splice body to elastically radially contract; and mounting the splice body assembly on the splice connection, including: positioning the pre-expanded splice body assembly adjacent the cable splice connection; and removing the holdout from the splice body assembly to permit the splice body to elastically radially contract onto the cable splice connection such that the layer of the conformable medium is radially interposed between and engages each of the interior surface of the splice body and an opposing interface surface of the cable insulation layer.

[0025] Peferably the method further includes mounting a tubular Faraday cage sleeve on the cable splice connection, wherein when the splice body assembly is mounted on the cable splice connection, the Faraday cage sleeve is radially interposed between the cable splice connection and the conformable medium.

Brief Description of the Drawings

[0026]

FIG. 1 is a perspective view of a pre-expanded cover assembly unit according to embodiments of the present invention.

FIG. 2 is a cross-sectional view of the pre-expanded cover assembly unit **of FIG.** 1 taken along the line **2-2 of FIG. 1.**

FIG. 3 is a perspective view of a splice body assembly and a holdout forming a part of the pre-expanded cover assembly of **FIG. 1,** wherein a splice body thereof is shown in transparency.

FIG. 4 is a fragmentary, perspective view of an exemplary polymeric insulated power transmission cable for use with the pre-expanded cover assembly unit of **FIG. 1.**

FIG. 5 is a cross-sectional view of a connection assembly including a cover assembly of the pre-expanded cover assembly unit of **FIG. 1** mounted on a splice connection.

FIG. 6 is a lengthwise cross-sectional view of a pre-expanded cover assembly unit according to further embodiments of the present invention.

FIG. 7 is a cross-sectional view of a connection assembly including a cover assembly of the pre-expanded cover assembly unit of **FIG. 6** mounted on a splice connection.

FIG. 8 is a lengthwise cross-sectional view of a pre-expanded cover assembly unit according to further embodiments of the present invention.

FIG. 9 is a cross-sectional view of a connection assembly including a cover assembly of the pre-expanded cover assembly unit of **FIG. 8** mounted on a splice connection.

FIG. 10 is a lengthwise cross-sectional view of a pre-expanded cover assembly unit according to further embodiments of the present invention.

FIG. 11 is a cross-sectional view of a connection assembly including a cover assembly of the pre-expanded cover assembly unit of **FIG. 10** mounted on a splice connection.

Detailed Description of Embodiments of the Invention

[0027] The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which illustrative embodiments of the invention are shown. In the drawings, the relative sizes of regions or features may be exaggerated for clarity. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0028] It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present invention.

[0029] Spatially relative terms, such as "beneath", "below", "lower", "above", "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90° or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0030] As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless expressly stated otherwise. It will be further understood that the terms "includes," "comprises," "including" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. It will be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0031] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0032] As used herein, "cold-applied" or "cold-applied cover" means that the cover or component can be assembled or installed about a substrate (e.g., a cable) without requiring the use of applied heat at the time of installation.

[0033] As used herein, "cold shrink" or "cold shrink cover" means that the cover or component can be shrunk or contracted about a substrate (e.g., a cable) without requiring the use of applied heat.

[0034] With reference to **FIGS. 1-5,** a cover assembly **100** according to some embodiments of the present invention is shown therein. The cover assembly **100** may be provided as a pre-expanded cover assembly unit **101** including a holdout device **102,** as shown in **FIGS. 1** and **2,** wherein the cover assembly **100** is in an expanded state or position.

[0035] The cover assembly **100** may be used to cover and electrically insulate electrical substrates such as cables and connectors. The cover assembly **100** may be used to cover and seal a connection or splice between two or more cables **40, 50** including an electrical connector **60** to form a connection assembly **10** as shown in **FIG. 5.** According to some embodiments, the cables **40, 50** are concentric neutral cables. According to some embodiments, the cables **40, 50** are metal tape shielded or longitudinally corrugated (LC) metal shielded cables.

[0036] The cover assembly **100** may be deployed and mounted on the intended substrate in a retracted state or position as shown in **FIG. 5** and discussed in more detail below. According to some embodiments, the cover assembly **100** is a cold shrink cover, meaning that it can be shrunk or retracted about the substrate without requiring the use of applied heat.

[0037] The cover assembly **100** includes a splice body assembly **120,** an outer sleeve (or re-jacket) **140,** and a metal shield mesh layer **146.** The splice body assembly **120** includes a splice body **130** and a tubular or layer of a flowable, conformable high permittivity material or medium ("the conformable medium") **150.** According to some embodiments and as discussed herein, the conformable medium of the layer **150** is a conformable, flowable, high electric permittivity (high-K) mastic.

[0038] The splice body **130** includes a tubular primary insulation sleeve or layer **132** and a semiconductor layer **138.**

[0039] The cover assembly **100** has a lengthwise axis **A-A.** The splice body assembly 120, the outer sleeve **140,** and the metal shield mesh layer **146** are provided as an integral, unitary structure extending lengthwise along the axis **A-A.** According to some embodiments, the cover assembly **100** is provided pre-installed and pre-expanded on the holdout **102.**

[0040] The splice body **130** has opposed inner and outer surfaces **130A** and 130B, and opposed axial terminal ends **130C, 130D.** The splice body **130** is tubular and the inner surface **130A** defines an axially extending conductor through passage **130E** that communicates with opposed end openings **130F, 130G.**

[0041] The primary insulation layer **132** is tubular and generally forms the bulk of the splice body **130** except for the semiconductor layer **138.** The primary insulation layer **132** has an inner surface **132A** defining the passage **130E.**

[0042] The primary insulation layer **132** can be formed of any suitable material. According to some embodiments, the primary insulation layer **132** is formed of a dielectric or electrically insulative material. According to some embodiments, the primary insulation layer **132** is formed of an elastically expandable material. According to some embodiments, the primary insulation layer **132**

is formed of an elastomeric material. According to some embodiments, the primary insulation layer **132** is formed of ethylene propylene diene monomer (EPDM) rubber. Other suitable materials may include liquid silicone rubber (LSR) or ethylene propylene rubber (EPR). According to some embodiments, the primary insulation layer **132** has a Modulus at 100 percent elongation (M100) in the range of from about 0.5 to 2.0 MPa.

[0043] According to some embodiments, the thickness of the primary insulation layer **132** is in the range from about 4 mm to 10 mm. According to some embodiments, the length **L1 (FIG. 2)** of the primary insulation layer **132** is in the range from about 250 mm to 750 mm.

[0044] The semiconductor layer **138** fully circumferentially surrounds the primary insulation layer **132.** According to some embodiments, the semiconductor layer **138** is coextensive with the primary insulation layer **132.**

[0045] The semiconductor layer **138** can be formed of any suitable electrically semiconductive material. According to some embodiments, the semiconductor layer **138** is formed of an elastically expandable material. According to some embodiments, the semiconductor layer **138** is formed of an elastomeric material. According to some embodiments, the semiconductor layer **138** is formed of carbon black and EPDM rubber. Other suitable materials may include carbon black and silicone.

[0046] The mastic layer **150** is tubular. The mastic layer **150** is adhered or bonded by its outer surface to the inner surface **130A** of the splice body **130.** The mastic layer **150** extends continuously from axial terminal end **150C** to axial terminal end **150D.**

[0047] According to some embodiments, the mastic layer **150** has a thickness **T1 (FIG. 2)** in the pre-expanded unit **101** in the range of from about 0.5 mm to 3 mm.

[0048] According to some embodiments and as illustrated, the mastic layer **150** spans at least a region extending from the end **130C** to the end **130D** of the splice body **130.** That is, the mastic layer **150** fully covers and is co-extensive with the primary insulation layer **132** *(i.e.,* ends **150C** and **150D** are substantially co-terminal with ends **130C** and **130D,** respectively), and is bonded to the primary insulation inner surface **130A** from the end **130C** to the end **130D.**

[0049] The mastic **150** may be any suitable type of mastic having the necessary or desired properties to function as intended. In particular, the mastic **150** should be sufficiently soft, at temperatures in the intended cold-applied installation and use temperature range, that it can conform to surfaces of the cables **40, 50** as discussed below, and should be a high-K material having adequate electric permittivity and dielectric strength to provide electric stress control and interfacial dielectric strength at an electrical interface as discussed below. As used herein, "high-K material" means a material having a dielectric constant *(i.e.,* relative permittivity) of at least 10.

[0050] According to some embodiments, the mastic **150** has a dielectric constant of at least about 10. According to some embodiments, the mastic **150** has a dielectric constant in the range of from about 10 to 30 and, in some embodiments, in the range of from about 15 to 25.

[0051] According to some embodiments, the mastic **150** has a volume resistivity in the range of from about 10^8 to 10^{14} Ohm-cm.

[0052] According to some embodiments, the mastic **150** has a dielectric strength in the range of from about 250 to 700 Volts/mil.

[0053] According to some embodiments, the mastic **150** is a silicone rubber-based mastic.

[0054] According to some embodiments, the mastic **150** has a plasticity number in the range of from about 150 to 650 according to ISO 7323.

[0055] According to some embodiments, the mastic **150** has a density in the range of from about 1.3 to 1.6 g/cm^3.

[0056] The shield mesh layer **146** fully circumferentially surrounds the splice body 130. According to some embodiments, the shield mesh layer **146** includes opposed end sections that extend beyond the ends of the splice body **130** but do not extend as far out as the outer sleeve **140.** The shield mesh layer **146** may be formed of braided or woven copper filaments, for example.

[0057] The outer sleeve **140** has opposed inner and outer surfaces **140A** and **140B,** and opposed ends **142A, 142B.** The outer sleeve **140** is tubular and defines an axially extending conductor through passage **143** that communicates with opposed end openings at the ends **142A, 142B.** When mounted on the holdout **102** as shown in **FIGS. 1** and **2,** outer sections **149** of the outer sleeve **140** are folded back on an intermediate section **148** of the outer sleeve **140** at annular folds **149A.**

[0058] The outer sleeve **140** can be formed of any suitable material. According to some embodiments, the outer sleeve **140** is formed of an electrically insulative material. According to some embodiments, the outer sleeve **140** is formed of an elastically expandable material. According to some embodiments, the outer sleeve **140** is formed of an elastomeric material. According to some embodiments, the outer sleeve **140** is formed of ethylene propylene diene monomer (EPDM) rubber. Other suitable materials may include neoprene or other rubber. According to some embodiments, the outer sleeve **140** has a Modulus at 100 percent elongation (M100) in the range of from about 0.6 to 1.1 MPa.

[0059] According to some embodiments, the thickness of the outer sleeve **140** is in the range of from about 0.11 to 0.25 inch. According to some embodiments, the length of the outer sleeve **140** is in the range of from about 15 to 35 inches.

[0060] The holdout **102** can be formed of any suitable material. The holdout **102** has an outer surface **106** and defines a through passage **108.** According to some embodiments, the holdout **102** includes a flexible strip **104** helically wound to form a rigid cylinder and having a pull tab or end segment **102A** extending through the passage **108** as illustrated, for example. According to some embodiments, the holdout **102** is formed of a semi-rigid polymeric material. According to some embodiments, the holdout **102** is formed of polypropylene, ABS, or PVC. The holdout device **102** may be factory installed.

[0061] The splice body assembly **120,** the cover assembly **100,** and the pre-expanded unit 101 may be formed by any suitable method and apparatus. According to some embodiments, the mastic layer **150** is pre-mounted on the outer surface **106** of the holdout **102,** and the splice body **130** is thereafter installed over the holdout **102** and the mastic layer **150.**

[0062] According to some embodiments, the primary insulation layer **132** is formed by extruding. In particular, in some embodiments, the primary insulation layer **132** is formed of EPDM rubber and is formed by extruding.

[0063] In some embodiments, the cover assembly **100** is formed by the following manufacturing process: a) the mastic **150** is pre-mounted on the holdout **102;** b) the primary insulation layer **132** and the semiconductor layer **138** are co-extruded as a continuous tube; c) optionally, the primary insulation layer **132** and the semiconductor layer **138** may then be cross-linked (*e.g.,* by heating the co-extruded tube to a prescribed temperature for a prescribed time); d) the co-extruded tube is cut to form the primary insulation layer **132** and the semiconductor layer **138;** and e) thereafter, the combined primary insulation layer **132** and semiconductor layer **138** structure *(i.e.,* the splice body **130)** is expanded, placed around the pre-mounted mastic **150** and the holdout **102** and permitted to contract about the mastic **150** and the holdout **102.**

[0064] In some embodiments, the cover assembly **100** is formed by the following manufacturing process: a) the mastic **150** is pre-mounted on the holdout **102;** b) the primary insulation layer **132** is extruded as a continuous tube; c) the semiconductor layer **138** is applied or coated onto the outer surface of the primary insulation layer **132** tube by painting, dipping or spraying, for example; d) the coated primary insulation layer tube is cut to form the primary insulation layer **132** and the semiconductor layer **138;** and e) thereafter, the combined primary insulation layer **132** and semiconductor layer **138** structure (*i.e.,* the splice body **130)** is expanded, placed around the pre-mounted mastic **150** and the holdout **102** and permitted to contract about the mastic **150** and the holdout **102.**

[0065] According to some embodiments, when mounted on the holdout **102,** the splice body **130** is maintained in an elastically radially expanded state or position. According to some embodiment, in the expanded state the splice body **130** is expanded in the range of from about 400 to 200 percent of its relaxed diameter. As a result, the splice body **130** of the pre-expanded unit **101** will exert a radially compressive pressure or load on the mastic layer **150** (which is constrained on its interior side by the rigid holdout **102).** According to some embodiments, this compressive load is in the range of from about 5 psi to 25 psi. According to some embodiments, in spite of this compressive loading, the mastic **150** will retain its general shape and position and will resist bleed out of oil, which might otherwise migrate within the interstices of the holdout **102.**

[0066] Referring now to **FIG. 5,** the cover assembly **100** may be applied over a splice connection **15** between a pair of electrical power transmission cables **40, 50** to form a connection assembly **10.** According to some embodiments, the cables **40, 50** are medium-voltage (*e.g.,* between about 5 and 35 kV) or high-voltage (*e.g.,* between about 46 and 230 kV) power transmission cables.

[0067] As shown in **FIG. 4,** the cable **40** includes a primary electrical conductor **42,** a polymeric insulation layer **44,** a semiconductor layer **45,** a metal electromagnetic radiation shield layer **46,** and a jacket **48,** with each component being concentrically surrounded by the next.

[0068] According to some embodiments and as shown, the shield layer **46** is a metal tape, foil, strip or sheath fully circumferentially surrounding the semiconductor layer **45** along the length of the cable. The metal strip may be longitudinally or helically wrapped about the semiconductor layer **45,** for example. According to some embodiments, the cable **40** is an LC shielded cable and the shield layer **46** is a thin corrugated metal layer. In other embodiments, the shield layer **46** may include individual wires, which may be helically wound about the semiconductor layer **45.**

[0069] The primary conductor **42** may be formed of any suitable electrically conductive materials such as copper (solid or stranded). The polymeric insulation layer **44** may be formed of any suitable electrically insulative material such as crosslinked polyethylene (XLPE) or EPR. The semiconductor layer **45** may be formed of any suitable semiconductor material such as carbon black with silicone. The shield layer **46** may be formed of any suitable material such as copper. The jacket **48** may be formed of any suitable material such as EPDM rubber or PVC.

[0070] The cable **50 (FIG. 5)** is similarly constructed with a primary electrical conductor **52,** a polymeric insulation layer **54,** a semiconductor layer **55,** a metal shield layer **56,** and a jacket **58** corresponding to components **42, 44, 45, 46** and **48,** respectively.

[0071] The connection assembly **10** may be formed and the cover assembly **100** may be installed as follows. The cables **40, 50** are prepared as shown in **FIG. 5** such that a segment of each layer extends beyond the next overlying layer.

[0072] The pre-expanded unit **101** is slid over one of the cables **40, 50.** According to some embodiments, the inside diameter of the holdout **102** is greater than the outer diameter of each cable **40, 50** and the connector **60** such that the inner diameter of the holdout **102** is sufficient to receive the prepared cable **40, 50** and the connector **60** without undue effort. According to some embodiments, the inner diameter of the holdout **102** is at least as great as the outer diameter of the largest portion of the cables or connector that are to be received in the cover assembly **100.** The pre-expanded unit **101** may be retained or parked on a cable **40, 50** until the operator is ready to install the cover assembly **100** on the cables **40, 50.**

[0073] The electrical connector **60** is secured to each primary conductor **42, 52** to mechanically and electrically couple the primary conductors **42, 52** to one another as shown in **FIG. 5.** The connector **60** may be any suitable type of connector such as a metal crimp connector.

[0074] The pre-expanded unit **101** is then slid into position over the connector **60.** The holdout **102** is then removed from the cover assembly **100,** thereby permitting the elastomeric sleeves **130, 140** to relax and radially retract about the cables **40, 50** and the connector **60** as shown in **FIG. 5,** as discussed in more detail below. According to some embodiments, the mastic **150** overlaps and engages the semiconductor layers **45, 55** of the cables **40, 50.**

[0075] The mastic layer **150** preferentially adheres to the inner surface **130A** of the splice body **130** and separates or releases from the holdout strip **104.** The mastic layer **150** is thus sandwiched between the splice body **130** and the cables **40, 50** and directly engages the interface surfaces of the cables **40, 50** as shown in **FIG. 5.** The splice body **130** is not fully recovered to its relaxed state, and therefore continues to apply a persistent radially compressive load or pressure to the mastic layer **150.**

[0076] The shield mesh **146** is rolled outwardly onto the semiconductor layers **45, 55** as shown in **FIG. 5.** A retainer **180** (e.g., a metal mesh web or clamp) can be wrapped about each cable **40, 50** as also shown in **FIG. 5** to secure the end edges of the shield mesh **146.** The retainers **180** may be wrapped about exposed ends of the shield layers **46, 56** to electrically connect the shield mesh **146** to the shield layers **46, 56.**

[0077] Strips of flowable sealant **66 (FIG. 5)** are applied to the outer surfaces of the cable jackets **48, 58.** According to some embodiments, the sealant **66** is a mastic. The operator then rolls each of the extension sections **149** of the outer sleeve **140** axially outwardly to cover the adjacent sections of the cables **40** and **50,** respectively. According to some embodiments, at least a portion of each extension section **149** overlaps a respective portion of each cable jacket **48, 58** and engages the associated sealant strip **66** to provide a moisture seal. According to some embodiments, the axial length of overlap between each extension section **149** and the underlying jacket **48, 58** is at least 1 inch.

[0078] The relaxed inner diameter of the outer sleeve **140** is less than at least the outer diameter of the jacket layers **48, 58.** Therefore, the outer sleeve **140** exerts a radially inwardly compressive or clamping force or pressure (due to elastic tension) onto the cables **40, 50.** The outer sleeve **140** may thereby effect a liquid tight seal at the interfaces between the extension sections **149** and the cable jackets **48, 58** and at the interfaces between the cable jackets **48, 58** and the outer sleeve **140.** These seals can protect the cable and the splice from the ingress of environmental moisture.

[0079] The relaxed inner diameter of the splice body **130** is less than at least the outer diameter of the cable insulation layers **44, 54.** Therefore, the splice body **130** exerts a radially inwardly compressive or clamping force or pressure (due to elastic tension) onto the cables **40, 50** and the mastic layer **150.** According to some embodiments, the relaxed inner diameter of the primary insulation layer **132** is at least 10% less than the smallest diameter cable upon which the cover assembly **100** is intended to be installed.

[0080] The cover assembly **100** is thereby fully installed to form the connection assembly **10** as shown in **FIG. 5.** As shown, the splice body assembly **120** and the splice connection **15** are relatively arranged and configured such that the mastic layer **150** forms an axially and circumferentially continuous tube surrounding the cables **40, 50** and the connector **60** from the cable semiconductor layer **45** to the cable semiconductor layer **55** (and also overlapping the semiconductor layers **45, 55).** The mastic layer **150** is thus interposed between and engages each of the inner surface **130A** of the splice body **130** and opposing interface surfaces of the connector **60,** the cable insulations **44, 54,** and the cable semiconductor layers **45, 55.** That is, the mastic layer **150** surrounds and engages the cables **40, 50** and the connector **60** across the entirety of the region from the end **130C** to the end **130D** of the splice body **130.**

[0081] Notably, in this manner, the high permittivity void filling mastic **150** extends along (and engages the cable throughout) the entire electrical interface. The electrical interface is here defined as the interface between the splice body assembly **120** and the cables **40, 50** extending axially from the terminal edge **45A** of the cable semiconductor layer **45** to the terminal edge **44A** of the cable insulation **44** and from the terminal edge **55A** of the cable semiconductor layer **55** to the terminal edge **54A** of the cable insulation **54.** The high permittivity void filling mastic **150** also extends along the entirety of the connector region *(i.e.,* the axial extent of the connector **60).**

[0082] According to some embodiments, the mastic layer **150** has a length **L2** (when installed; **FIG. 5)** in the range of from about 250 to 750 mm.

[0083] According to some embodiments, the mastic layer **150,** when installed, has a thickness **T2 (FIG. 5)** in the range of from about 1 to 8 mm.

[0084] In some embodiments, the mastic layer **150** overlaps the cable semiconductor layers **45, 55** a distance **L3 (FIG. 5)** in the range of from about 15 to 50 mm.

[0085] The pre-expanded unit **101,** and particularly the splice body assembly **120,** and the mastic layer **150,** can provide significant advantages during installation and in service. The electrical interface between a splice body and spliced cables is typically the weakest link in the insulation system of a medium or high voltage joint. In particular, joint failures tend to be initiated by insulation failures along this electrical interface, which is the interface between the cable insulation and the joint or splice body extending from the Faraday cage to the stress cone, which may be referred to as the creepage distance.

[0086] Electrical interfaces between cables and splice bodies may be electrically weak compared to the bulk dielectric strength of the primary splice body insulation for a number of reasons. The interface between the cable and the splice body is imperfect and contains small amounts of air (*e.g.,* in microvoids) that electrically ionize in the electrical field and can cascade into complete dielectric breakdown. The cable insulation is exposed during installation and can become contaminated with water or other conductive contaminants.

[0087] To address the foregoing concerns, it is known in the prior art to hand apply silicone grease along the interface prior to installation of the splice body to fill voids and increase dielectric strength. However, problems occur when the grease is contaminated during installation or partially applied or not applied at all, which can lead to dielectric breakdown.

[0088] Apparatus and methods according to embodiments of the present invention can address the foregoing concerns by providing a high permittivity, high dielectric strength, conformable mastic layer **150** integrally applied with the cold-shrink splice body **130** to the interface surfaces (including the electrical interface surfaces) of the cables **40, 50** (while also engaging the splice body interface surface **130A),** which increases the electrical reliability of the electrical interfaces and may at the same time remedy the installation deficiencies as described above for silicone grease.

[0089] The high permittivity, high dielectric strength mastic layer **150** (particularly when comprised of silicone rubber-based mastic as described hereinabove that remains flowable at room temperature) serves as a flowable, conformable medium between the splice body **130** and the cables **40, 50** that provides electrical stress control in the area over the central connector **60,** the insulating interfaces of the cable insulation **44, 54,** and the cutback sections of the semiconductor layers **45, 55.** The mastic layer **150** extending the entire length of the splice body **130** *(i.e.,* from end **130C** to end **130D)** and the entire electrical interface (not just over the connector and cable semiconductor layer cutbacks) can thus provide increased electrical stress control, interfacial dielectric strength, and electrical reliability.

[0090] According to some embodiments, the mastic **150** can flow at temperatures in the intended service range, including at room temperature. In some embodiments, the mastic **150** can flow at least at temperatures in the range of from about -20°C to 50°C. As such, the cover assembly **100** can be effectively and reliably cold-applied to the splice.

[0091] The mastic layer **150** applied and retained under the elastic pressure of the partially radially expanded splice body **130** will flow and conform to the irregularities of the exposed surfaces of the cables **40, 50** and the inner surface **130A** of the splice body **130,** thereby eliminating air voids (in surface microvoids or macrovoids) and electrically ionizable sites.

[0092] The mastic layer **150** can engulf and isolate contaminants to thereby increase the overall dielectric strength of the interface.

[0093] The mastic layer **150** can be factory-applied to the splice body **130** (to form the splice body assembly **120)** and factory-mounted on the holdout **102** (to form the pre-expanded unit **101** or a part thereof), and can be integrally applied to the splice connection **15** in a single step with the splice body **130.** As such, the risks that an installer may forget to apply the mastic or that the mastic may be contaminated are eliminated. The factory-applied mastic **150** also eliminates the need for separate application of mastics, Faraday cages, and void filling greases during the product installation process as may be required for known products and installation methods.

[0094] According to some embodiments (*e.g.,* when formed from a silicone-based mastic as described hereinabove), the mastic layer **150** is formulated to be stable under the elastic compression force of the splice body **130** while expanded on the holdout **102.** According to some embodiments, the mastic layer **150** is resistant to oil bleed out under pressure and does not migrate in between the interstices of the spiral holdout **102.**

[0095] According to some embodiments, an electrical connector of a different type may be used in place of the shear bolt connector **60.**

[0096] While an "all-in-one" cover assembly **100** has been shown and described, the splice body assembly **120** may be provided independently. For example, the splice body assembly **120** may be pre-mounted on the holdout **102** to form a pre-expanded splice body assembly without the shield mesh **146** and jacket **140** being mounted thereover. A shield layer and jacket may be separately installed on the splice connection 15 after the splice body assembly **120** has been installed.

[0097] With reference to **FIGS. 6** and 7, a cover assembly **200** according to further embodiments of the present invention is shown therein. The cover assembly **200** may be provided as a pre-expanded cover assembly unit **201** including a holdout device **102,** as shown in **FIG. 6,** wherein the cover assembly **200** is in an expanded state or position.

[0098] The cover assembly **200** may be used to cover and electrically insulate electrical substrates such as cables and connectors as described above with regard to the cover assembly **100.** The cover assembly **200** may be used to cover and seal a connection or splice between two or more cables 40, 50 including an electrical connector **60** to form a connection assembly **10** as shown in **FIG. 7.** The cover assembly **200** may be deployed and mounted on the intended substrate in a retracted state or position as described above with regard to the cover assembly **100** and as shown in **FIG. 7.**

[0099] The cover assembly **200** includes a splice body assembly **220.** The splice body assembly **220** includes a splice body **230** and a tubular layer of a flowable, high electrical permittivity, conformable material or medium ("the conformable medium") **250.** The pre-expanded cover assembly unit **201** may also include an outer sleeve corresponding to the outer sleeve (or re-jacket) **140** and a metal shield corresponding to the metal shield mesh layer **146,** which components are shown in **FIG. 7** as parts of the connection assembly **10.**

[0100] The splice body **230** includes a tubular primary insulation sleeve or layer **232,** an integral semiconductor layer **238,** and an integral, tubular, elastomeric, electrical stress control or high electrical permittivity (high-K) layer **234.**

[0101] The primary insulation layer **232,** the semiconductor layer **238,** and the medium **250** may be formed in the same manner and of the same materials as described above for the primary insulation layer **132,** the semiconductor layer **138,** and the medium **150,** respectively.

[0102] The cover assembly **200** differs from the cover assembly **100** in the further provision of the elastomeric, high permittivity layer **234** between the mastic **250** and the primary insulation layer **232.** The high permittivity layer **234** is adhered or bonded by its outer surface to the inner surface **230A** of the splice body **230.**

[0103] According to some embodiments and as illustrated, the stress control layer **234** spans at least a region extending from the end **230C** to the end **230D** of the splice body **230.** That is, the high permittivity layer **234** fully covers and is bonded to the primary insulation inner surface **232A** from the end **230C** to the end **230D.**

[0104] The high permittivity layer **234** can be formed of any suitable elastically expandable, high-K material. According to some embodiments, the high permittivity layer **234** is formed of an elastomeric material. According to some embodiments, the high permittivity layer **234** is formed of EPDM rubber. Other suitable materials may include silicone rubber. According to some embodiments, the high permittivity layer **234** has a Modulus at 100 percent elongation (M100) in the range of from about 0.5 to 2.0 MPa.

[0105] According to some embodiments, the high permittivity layer **234** has a dielectric constant of at least about 10. According to some embodiments, the high permittivity layer **234** has a dielectric constant in the range of from about 10 to 30 and, in some embodiments, 15 to 25.

[0106] According to some embodiments, the high permittivity layer **234** has a volume resistivity in the range of from about 10^{10} to 10^{14} Ohm-cm.

[0107] According to some embodiments, the high permittivity layer **234** has a dielectric strength in the range of from about 300 to 700 Volts/mil.

[0108] According to some embodiments, the thickness **T4 (FIG. 6)** of the high permittivity layer **234** is in the range from about 1 to 3 mm. According to some embodiments, the length **L4** of the high permittivity layer **234** is in the range from about 250 to 750 mm.

[0109] The splice body assembly **220,** the cover assembly **200,** and the pre-expanded unit **201** may be formed by any suitable method and apparatus. According to some embodiments, the mastic layer **250** is pre-mounted on the outer surface **206** of the holdout **102,** and the splice body **230** is thereafter installed over the holdout **102** and the mastic layer **250.**

[0110] According to some embodiments, the primary insulation layer **232** and the high permittivity layer **234** are formed by extruding.

[0111] In some embodiments, the cover assembly **200** is formed by the following manufacturing process: a) the mastic **250** is pre-mounted on the holdout **102;** b) the primary insulation layer **232,** the high permittivity layer **234** and the semiconductor layer **238** are co-extruded as a continuous tube; c) optionally, the primary insulation layer **232,** the high permittivity layer **234** and the semiconductor layer **238** may then be cross-linked (e.*g.,* by heating the co-extruded tube to a prescribed temperature for a prescribed time); d) the co-extruded tube is cut to form the primary insulation layer **232,** the high permittivity layer **234** and the semiconductor layer **238;** and e) thereafter, the combined primary insulation layer **232,** high permittivity layer **234** and semiconductor layer **238** structure *(i.e.,* the splice body **230)** is expanded, placed around the pre-mounted mastic **250** and the holdout **102** and permitted to contract about the mastic **250** and the holdout **102.**

[0112] In some embodiments, the cover assembly **200** is formed by the following manufacturing process: a) the mastic **250** is pre-mounted on the holdout **102;** b) the primary insulation layer **232** and the high permittivity layer **234** are extruded as a continuous tube; c) the semiconductor layer **238** is applied or coated onto to the outer surface of the primary insulation layer **232** tube by painting, dipping or spraying, for example; d) the coated multilayer tube is cut to form the primary insulation layer **232,** the high permittivity layer **234** and the semiconductor layer **238;** and e) thereafter, the combined primary insulation layer **232,** high permittivity layer **234** and semiconductor layer **238** structure *(i.e.,* the splice body **230)** is expanded, placed around the pre-mounted mastic **250** and the holdout **102** and permitted to contract about the mastic **250** and the holdout **102.**

[0113] The internal, integral, elastomeric high permittivity layer **234** serves to provide enhanced electrical stress control for higher voltage class cables.

[0114] With reference to **FIGS. 8** and **9,** a cover assembly **300** according to further embodiments of the present invention is shown therein. The cover assembly **300** may be provided as a pre-expanded cover assembly unit **301** including a holdout device **102,** as shown in **FIG. 8,** wherein the cover assembly **300** is in an expanded state or position.

[0115] The cover assembly **300** may be used to cover and electrically insulate electrical substrates such as cables and connectors as described above with regard to the cover assembly **100.** The cover assembly **300** may be used to cover and seal a connection or splice between two or more cables **40, 50** including an electrical connector **60** to form a connection assembly **10** as shown in **FIG. 9.** The cover assembly **300** may be deployed and mounted on the intended substrate in a retracted state or position as described above with regard to the cover assembly **100** and as shown in **FIG. 9.**

[0116] The cover assembly **300** includes a splice body assembly **320.** The splice body assembly **320** includes a splice body **330** and a tubular layer of a flowable, high electrical permittivity, conformable material or medium ("the conformable medium") **350.** The pre-expanded cover assembly unit **301** may also include an outer sleeve corresponding to the outer sleeve (or re-jacket) **140** and a metal shield corresponding to the metal shield mesh layer **146,** which components are shown in **FIG. 9** as parts of the connection assembly **10.**

[0117] The splice body **330** includes a tubular primary insulation sleeve or layer **332** and an integral semiconductor layer **338.** The primary insulation layer **332,** the semiconductor layer **338,** and the medium **350** may be formed in the same manner and of the same materials as described above for the primary insulation layer **132,** the semiconductor layer **138,** and the medium **150,** respectively.

[0118] The cover assembly **300** differs from the cover assembly **100** in the further provision of a tubular, elastomeric Faraday cage layer or sleeve **360** interposed between the mastic **350** and the holdout **102.** The Faraday cage sleeve **360** has opposed axial ends **360A, 360B** and a Faraday cage interface surface **362** defining a passage **364** extending from end **360A** to end **360B.** The ends **360A** and **360B** are spaced apart from the adjacent ends **332A** and **332B** of the primary insulation layer **332.**

[0119] The Faraday cage sleeve **360** may be formed of a suitable elastically conductive elastomer. According to some embodiments, the Faraday cage sleeve **360** is formed of EPR rubber. Other suitable materials may include silicone rubber. According to some embodiments, the Faraday cage sleeve **360** has a Modulus at 100 percent elongation (M100) in the range of from about 0.5 to 3 MPa.

[0120] According to some embodiments, the Faraday cage sleeve **360** has a volume resistivity in the range of from about 0.5×10^2 to 10^3 Ohm-cm.

[0121] According to some embodiments, the thickness **T5 (FIG. 8)** of the Faraday cage sleeve **360** is in the range from about 1 to 3 mm. According to some embodiments, the length **L5** of the Faraday cage sleeve **360** is in the range from about 75 to 225 mm.

[0122] In use, the Faraday cage sleeve **360** may form a Faraday cage to provide an equal potential volume about the connector **60** so that an electric field is cancelled in the surrounding air voids. As shown in **FIG. 9,** the cover assembly **300** can be installed on the splice connection **15** from the holdout **102** in the same manner as described above with regard to the cover assembly **100.** The installed Faraday cage sleeve **360** extends axially from the cable insulation **44** to the cable insulation **54,** and overlaps each of the insulations **44, 54.** In some embodiments, the Faraday cage sleeve **360** overlaps each insulation layer **44, 54** a distance **L9 (FIG. 9)** in the range of from about 15 to 50 mm.

[0123] The purpose of the elastomeric Faraday cage sleeve **360** is to provide electrical stress control in the event that the mastic **350** cannot fill all of the voids around the connector **60.** This may be desirable or required on larger cables where the void filling volume is large, and for higher voltage cables where the electric stress is high.

[0124] The splice body assembly **320,** the cover assembly **300,** and the pre-expanded unit **301** may be formed by any suitable method and apparatus. According to some embodiments, the mastic layer **350** is pre-mounted on the outer surface **106** of the holdout **102,** and the splice body **330** is thereafter installed over the holdout **102** and the mastic layer **350.**

[0125] According to some embodiments, the primary insulation layer **332** is formed by extruding.

[0126] In some embodiments, the cover assembly **300** is formed by the following manufacturing process: a) the Faraday cage sleeve **360** is expanded and mounted on the holdout **102;** b) the mastic **350** is pre-mounted over the Faraday cage sleeve **360** and the holdout **102;** and c) the splice body **330** is expanded, placed around the pre-mounted Faraday cage sleeve **360** and mastic **350** and the holdout **102,** and permitted to contract about the mastic **350** and the holdout **102.** The Faraday cage sleeve **360** may be formed by any suitable method such as molding or extrusion. The splice body **330** may be formed using the method or methods as described above for the cover assembly **100.**

[0127] According to further embodiments, the cover assembly **300** may also include an integral, elastomeric high permittivity layer corresponding to the elastomeric high permittivity layer **234** mounted between the mastic **350** and the primary insulation layer **332.**

[0128] According to further embodiments, the Faraday cage sleeve **360** may be provided separately from the mastic **350** and the splice body **330.** In this case, the installer may be provided with the expanded cover assembly **101** and the Faraday cage sleeve **360.** The Faraday cage sleeve **360** may be pre-mounted on a suitable holdout. The installer first installs the Faraday cage sleeve **360** on the splice connection **15** or other substrate, and thereafter installs the cover assembly **100** over the Faraday cage sleeve **360.** Alternatively, where an integral, elastomeric high permittivity layer **234** is also to be provided, the installer is provided with the expanded cover assembly **201** and installs the cover assembly **200** over the pre-installed Faraday cage sleeve **360.**

[0129] With reference to **FIGS. 10** and **11,** a cover assembly **400** according to further embodiments of the present invention is shown therein. The cover assembly **400** may be provided as a pre-expanded cover assembly unit **401** including a holdout device **102,** as shown in **FIG. 10,** wherein the cover assembly **400** is in an expanded state or position.

[0130] The cover assembly **400** may be used to cover and electrically insulate electrical substrates such as cables and connectors as described above with regard to the cover assembly **100.** The cover assembly **400** may be used to cover and seal a connection or splice between two or more cables **40, 50** including an electrical connector **60** to form a connection assembly **10** as shown in **FIG. 11.** The cover assembly **400** may be deployed and mounted on the intended substrate in a retracted state or position as described above with regard to the cover assembly **100** and as shown in **FIG. 11.**

[0131] The cover assembly **400** includes a splice body assembly **420.** The splice body assembly **420** includes a splice body **430,** three axially distributed, tubular layers of a flowable, high electrical permittivity, conformable material or medium **452, 454,** and two axially distributed, tubular layers of a flowable, electrically insulating, conformable material or medium **470, 472.** The pre-expanded cover assembly unit **401** may also include an outer sleeve corresponding to the outer sleeve (or re-jacket) **140** and a metal shield corresponding to the metal shield mesh layer **146,** which components are shown in **FIG. 11** as parts of the connection assembly **10.**

[0132] The splice body **430** includes a tubular primary insulation sleeve or layer **432** and an integral semiconductor layer **438.** The primary insulation layer **432,** the semiconductor layer **438,** and the high permittivity mediums **452, 454** may be formed in the same manner and of the same materials as described above for the primary insulation layer **132,** the semiconductor layer **138,** and the medium **150,** respectively.

[0133] The cover assembly **400** differs from the cover assembly **100** in the further provision of the tubular, electrically insulating mastic layers **470, 472** interposed the primary insulation layer **432** and the holdout **102** and axially spanning regions **R1.** The adjacent or proximal ends **470B, 472A** of the insulating mastic layers **470, 472** are spaced apart from one another so that the high permittivity mastic layer **452** axially spans a region **R2** extending from the mastic end **470B** to the mastic end **472A.** The opposing or distal ends **470A, 472B** of the insulating mastic layers **470, 472** are spaced apart from the ends **432A, 432B** of the primary insulation layer **432** so that the high permittivity mastic layers **454** axially span opposed regions **R3** extending from insulating mastic end **470A** to the primary insulation end **432A** and from insulating mastic end **472B** to primary insulation end **432B,** respectively. The inner surfaces of the insulating mastic layers **470, 472** and the high permittivity mastic layers **452, 454** collectively define a passage **477** extending from end **432A** to end **432B.**

[0134] The mastics **470, 472** may be any suitable type of mastic having the necessary or desired properties to function as intended. In particular, the mastics **470, 472** should be sufficiently soft, at temperatures in the intended cold-applied installation and use temperature range, that it can conform to surfaces of the cables **40, 50** as discussed below, and should be an electrically insulating material having adequate conformability and dielectric strength to provide electrical insulation and interfacial dielectric strength at an electrical interface as discussed below. As used herein, "electrically insulating material" means a material having a dielectric strength of at least 250 volts/mil.

[0135] The insulating mastics **470, 472** each have a substantially lower dielectric constant (lower relative permittivity) than the high permittivity mastics **452, 454.** According to some embodiments, the mastics **470, 472** have a dielectric constant of at least about 2. According to some embodiments, the mastics **470, 472** have a dielectric constant in the range of from about 2 to 8 and, in some embodiments, in the range of from about 4 to 8.

[0136] According to some embodiments, the mastics **470, 472** have a volume resistivity in the range of from about 10^{12} to 10^{15} Ohm-cm.

[0137] According to some embodiments, the mastics **470, 472** have a dielectric strength in the range of from about 250 to 800 Volts/mil.

[0138] According to some embodiments, the mastics **470, 472** are silicone rubber-based mastics.

[0139] According to some embodiments, the mastics **470, 472** have a plasticity number in the range of from about 150 to 650 according to ISO 7323.

[0140] According to some embodiments, the mastics **470, 472** have a density in the range of from about 1.3 to 1.6 g/cm^3.

[0141] According to some embodiments, the thickness **T6 (FIG. 10)** of each of the mastic layers **470, 472** is in the range from about 1 to 3 mm. According to some embodiments, the length **L6** of each of the mastics **470, 472** is in the range from about 30 to 70 mm.

[0142] According to some embodiments, the length **L7** of the portion of the high permittivity mastic layer **452** extending between the ends **470B** and **472A** is in the range from about 130 to 360 mm. According to some embodiments, the length **L8** of the portion of the high permittivity mastic layers **454** extending between the ends **470A** and the ends **432A** and **432B,** respectively, is in the range from about 65 to 170 mm.

[0143] In use and as shown in **FIG. 11,** the cover assembly **400** can be installed on the splice connection **15** from the holdout **102** in the same manner as described above with regard to the cover assembly **100.** As shown in **FIG. 11,** each insulating mastic layer **470, 472** is interposed between and engages each of the inner surface **430A** of the splice body **430** and opposing interface surfaces **44B, 54B** of the cable insulation layers **44, 54** and the cable semiconductor layers **45, 55.** The splice body assembly **420** is configured and positioned relative to the splice connection **15** such that each insulating mastic layer **470, 472** surrounds and engages the cable insulation **44, 54** across the most of the regions of the exposed insulation **44, 54.** According to some embodiments, each insulating mastic layer **470, 472** surrounds and engages the cable insulation **44, 54** at least from a terminal edge **44A, 54A** of the insulation layer **44, 54** to the proximal edge of the adjacent high permittivity mastic layer **454** such that the entireties of the exposed insulations **44, 54** are covered by the mastics **454, 470, 472.** The high permittivity mastic layers **452, 454** surround the terminal edges **45A, 55A** of the semiconductor layers **45, 55** and overlap adjacent sections of the semiconductor layers 45, 55 and the cable insulations **44, 54.**

[0144] Thus, it can be seen that in some embodiments (*e.g.,* as shown in **FIG. 11),** the splice body assembly **420** and the splice connection **15** are relatively arranged and configured such that the insulating mastic layers **470, 472** and the high permittivity mastic layers **452, 454** collectively form an axially and circumferentially continuous tube surrounding the cables **40, 50** and the connector **60** from the cable semiconductor layer **45** to the cable semiconductor layer **55** (and also overlapping the semiconductor layers **45, 55).**

[0145] Advantageously, arrangement of the mastic layers **452, 454, 470, 472** can provide higher electrical strength because insulating mastic generally has higher dielectric strength than high permittivity mastic.

[0146] The splice body assembly **420,** the cover assembly **400,** and the pre-expanded unit **401** may be formed by any suitable method and apparatus. According to some embodiments, the mastic layers **452, 454, 470, 472** are pre-mounted on the outer surface **106** of the holdout **102,** and the splice body **430** is thereafter installed over the holdout **102** and the mastic layers **452, 454, 470, 472.**

[0147] According to some embodiments, the primary insulation layer **432** is formed by extruding.

[0148] In some embodiments, the cover assembly **400** is formed by a manufacturing process as described above for the cover assembly **100** except that the insulating mastic layer **470, 472** are mounted on the holdout **102** prior to or along with the mastic layers **452, 454.**

[0149] According to further embodiments, the cover assembly **400** may also include an integral, elastomeric high permittivity layer corresponding to the elastomeric high permittivity layer **234** mounted between the mastic layers **452, 454, 470, 472** and the primary insulation layer **432.**

[0150] The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

Claims

1. A pre-expanded cover assembly (201) for protecting a cable splice connection (15) including cables (40, 50) and a connector (60), the cables (40, 50) including electrical conductors (42, 52) surrounded by cable insulation layers (44, 54), the pre-expanded cover assembly (201) comprising:

   a splice body assembly (220) including:

      a tubular, cold-shrinkable, electrically insulative, elastomeric splice body (230) having an interior surface (230A) defining an interior passage; and
      a tubular layer of a conformable medium (250) pre-mounted on the interior surface of the splice body (230), wherein the conformable medium (250) is a flowable material having a high electrical permittivity; and

   a removable holdout (102), wherein the splice body assembly (220) is mounted on the holdout (102) such that the holdout maintains the splice body (230) in an elastically radially expanded state, and the holdout (102) is selectively removable from the splice body (230) to permit the splice body to elastically radially contract;
   wherein the layer of the conformable medium (250) is positioned and
   configured such that, when the pre-expanded cover assembly is positioned adjacent the cable splice connection (15), the holdout (102) is removed from the splice body (230), and the splice body (230) elastically radially contracts onto the cable splice connection (15), the layer of the conformable medium (250) will be radially interposed between and engage each of the interior surface (230A) of the splice body (230) and an opposing interface surface of the cable insulation; and
   characterized in that the splice body (230) includes:

      (i) a tubular primary insulation layer (232) formed of an electrically insulating elastomer; and
      (ii) an integral, tubular inner elastomeric layer (234) radially interposed between the primary insulation layer (232) and the conformable medium (250), wherein the inner elastomeric layer (234) is formed of an elastomer having high permittivity.

2. The pre-expanded cover assembly of Claim 1 wherein the primary insulation layer (232) is formed of extruded silicone or ethylene propylene diene monomer (EPDM) rubber.

3. The pre-expanded cover assembly of Claim 2 wherein the splice body (230) further includes a semiconductor layer (238) covering an outer surface of the primary insulation layer (232).

4. The pre-expanded cover assembly of Claim 1 wherein the conformable medium (250) is a mastic.

5. The pre-expanded cover assembly of Claim 4 wherein the mastic (250) has a dielectric constant in the range of from about 15 to 25.

6. The pre-expanded cover assembly of Claim 4 wherein:

the mastic (250) is a silicone rubber-based mastic that has a plasticity number in the range of from about 150 to 650 according to ISO 7323 and is deformable at all temperatures in the range of -20°C to 50°C; and
the mastic has a dielectric strength in the range of from about 250 Volts/mil to 700 Volts/mil.

7. The pre-expanded cover assembly of Claim 1 wherein the holdout (102) includes a tubular holdout formed by a helically wound strip, and the holdout is configured to be removed from the splice body assembly (220) by pulling the strip.

8. The pre-expanded cover assembly of Claim 1 wherein:

the primary insulation layer (232) extends from a first axial end (230C) to an opposed second axial end (230D);
the interior passage terminates at the first and second axial ends; and
the inner elastomeric layer (234) extends continuously from the first axial end to the second axial end.

9. The pre-expanded cover assembly of Claim 8 wherein an outer surface of the inner elastomeric layer (234) is bonded to an inner surface (232A) of the primary insulation layer (232).

10. The pre-expanded cover assembly of Claim 8 wherein the tubular layer of mastic (250) extends continuously from the first axial end (230C) to the second axial end (230D).

11. A method of manufacturing a pre-expanded cover assembly (201) for protecting a cable splice connection (15) including cables (40, 50) and a connector (60), the cables (40, 50) including electrical conductors (42, 52) surrounded by cable insulation layers (44, 54), the method comprising:

mounting a tubular layer of a conformable medium (250) on a removable holdout (102), wherein the conformable medium (250) is a flowable material having a high electrical permittivity; and thereafter
mounting a tubular, cold-shrinkable, electrically insulative, elastomeric splice body (230) on the holdout (102) over the conformable medium (250) such that the holdout (102) maintains the splice body (230) in an elastically radially expanded state and an interior surface of the splice body (230) defines an interior passage and engages the conformable medium (250);
wherein the holdout (102) is selectively removable from the splice body (230) to permit the splice body (230) to elastically radially contract; and
wherein the layer of the conformable medium (250) is positioned and configured such that, when the pre-expanded cover assembly (201) is positioned adjacent the cable splice connection (15), the holdout (102) is removed from the splice body (230), and the splice body (230) elastically radially contracts onto the cable splice connection (15), the layer of the conformable medium (250) will be radially interposed between and engage each of the interior surface (230A) of the splice body (230) and an opposing interface surface of the cable insulation; and
characterized in that the splice body (230) includes:

(i) a tubular primary insulation layer (232) formed of an electrically insulating elastomer; and
(ii) an integral, tubular inner elastomeric layer (234) radially interposed between the primary insulation layer (232) and the conformable medium (250), wherein the inner elastomeric layer (234) is formed of an elastomer having high permittivity.

12. The method of Claim 11 wherein:

the primary insulation layer extends from a first axial end (230C) to an opposed second axial end (230D);
the interior passage terminates at the first and second axial ends;
the inner elastomeric layer (234) extends continuously from the first axial end to the second axial end; and
the method includes forming the splice body by co-extruding the primary insulation layer (232) and the inner elastomeric layer (234).

13. The method of Claim 12 wherein an outer surface of the inner elastomeric layer (234) is bonded to an inner surface of the primary insulation layer (232).

14. The method of Claim 12 wherein the tubular layer of mastic (250) extends continuously from the first axial end (230C) to the second axial end (230D).

15. A method for protecting a cable splice connection (15) including cables (40, 50) and a connector (60),

the cables (40, 50) including electrical conductors (42, 52) surrounded by cable insulation layers (44, 54), the method comprising:
providing a pre-expanded cover assembly (201) comprising:

a splice body assembly (220) including:

a tubular, cold-shrinkable, electrically insulative, elastomeric splice body (230) having an interior surface defining an interior passage; and
a tubular layer of a conformable medium (250) pre-mounted on the interior surface of the splice body (230), wherein the conformable medium (250) is a flowable material having a high electrical permittivity; and

a removable holdout (102), wherein the splice body assembly (220) is mounted on the holdout (102) such that the holdout (102) maintains the splice body (230) in an elastically radially expanded state, and the holdout (102) is selectively removable from the splice body (230) to permit the splice body (230) to elastically radially contract;

wherein the splice body (230) includes:

(i) a tubular primary insulation layer (232) formed of an electrically insulating elastomer; and
(ii) an integral, tubular inner elastomeric layer (234) radially interposed between the primary insulation layer (232) and the conformable medium (250), the inner elastomeric layer (234) being formed from an elastomer having high permittivity; and

mounting the splice body assembly (220) on the splice connection (15), including:

positioning the pre-expanded splice body assembly (201) adjacent the cable splice connection (15); and
removing the holdout (102) from the splice body assembly (220) to permit the splice body (230) to elastically radially contract onto the cable splice connection (15) such that the layer of the conformable medium (250) is radially interposed between and engages each of the interior surface of the splice body (230) and an opposing interface surface of the cable insulation layer.

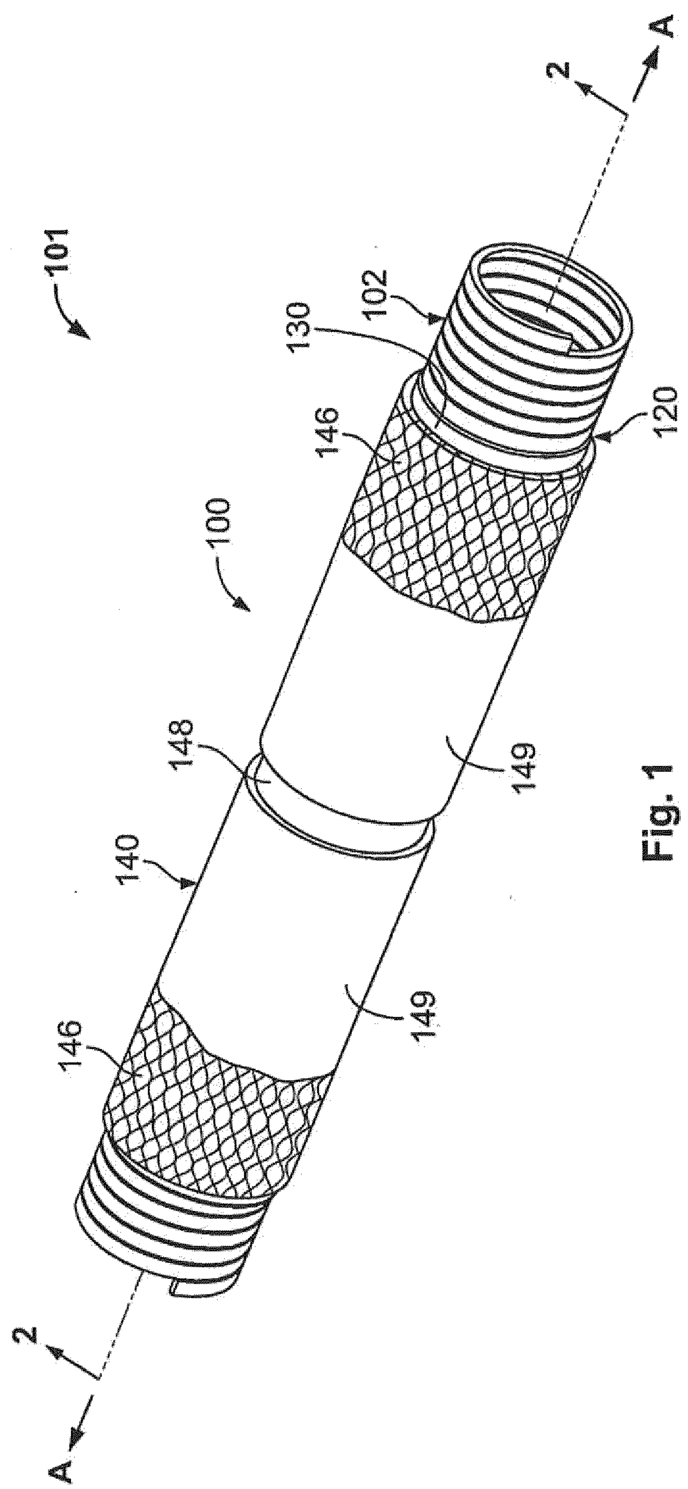

Fig. 1

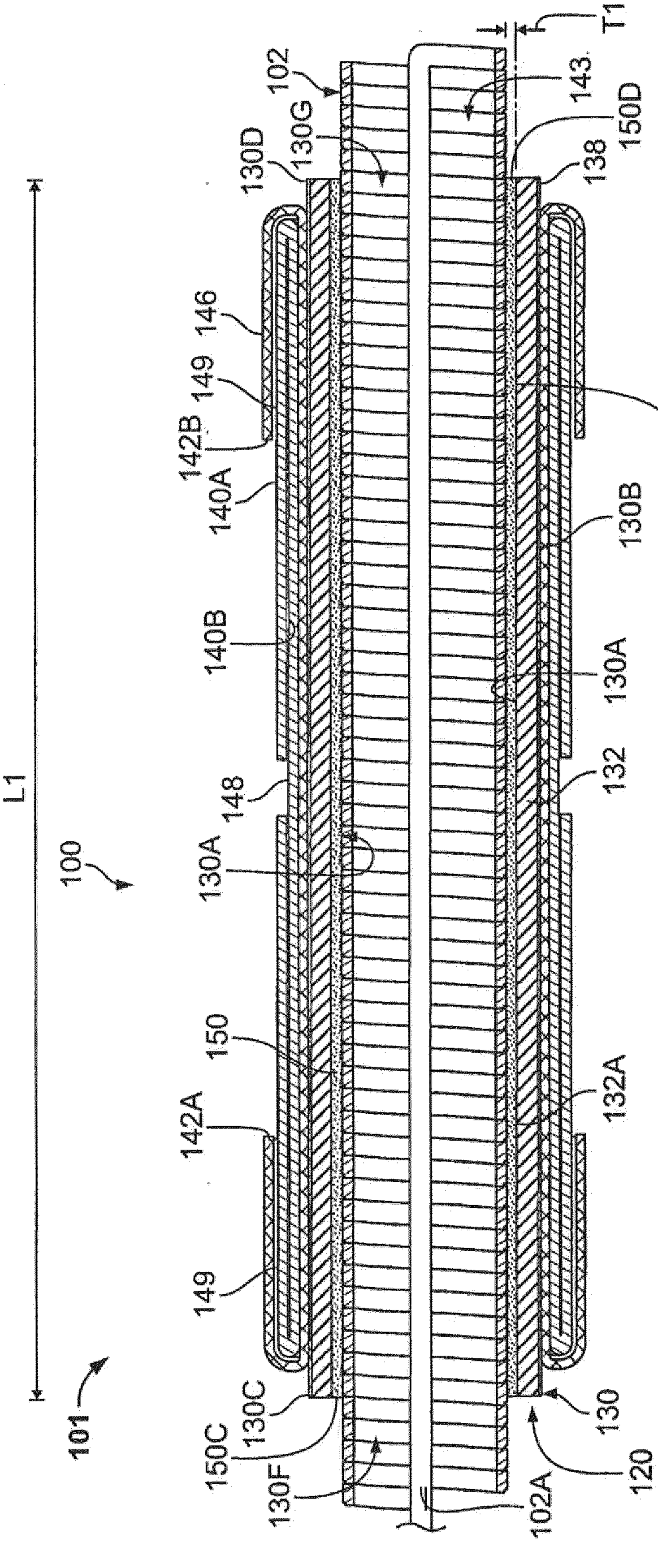
T1
102
143
130G
150D
130D
138
146
149
142B
132A
140A
130B
140B
130A
L1
148
132
100
130A
150
132A
142A
149
101
130C
130
150C
120
130F
102A

Fig. 2

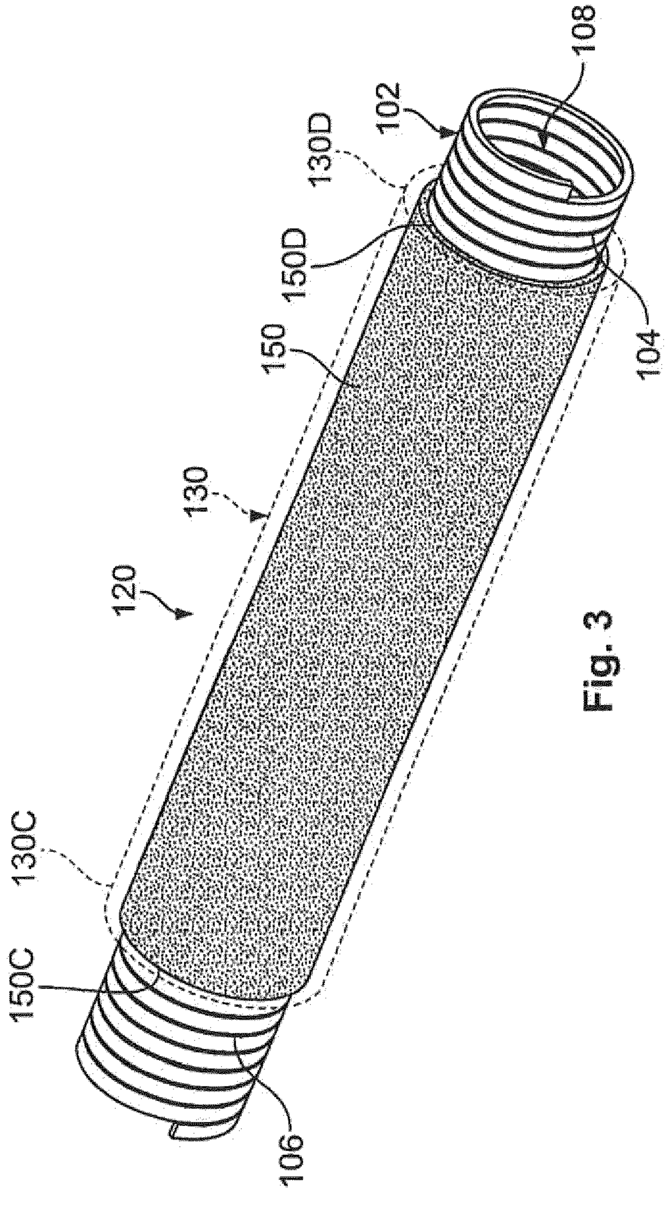

Fig. 3

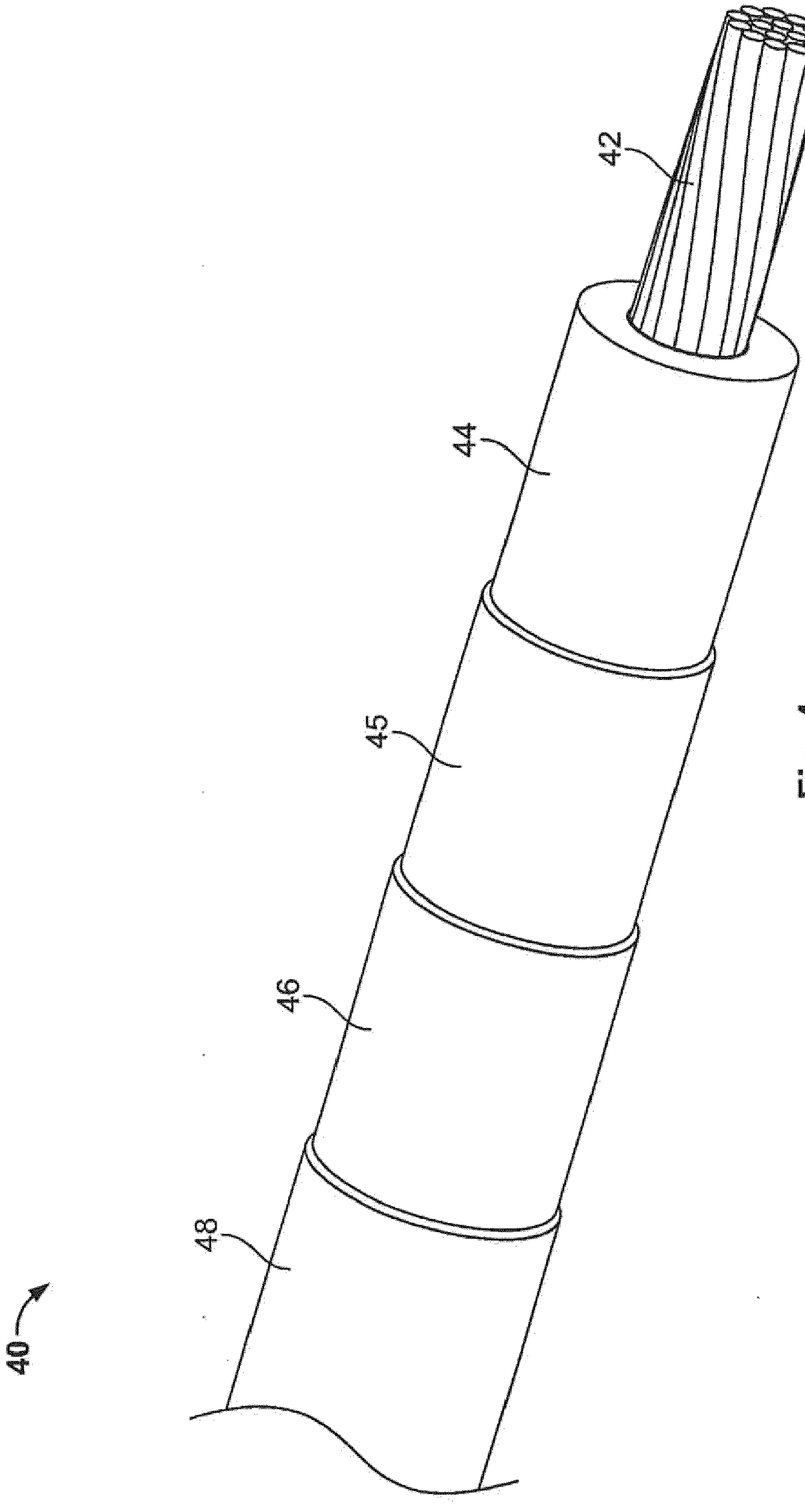

Fig. 4

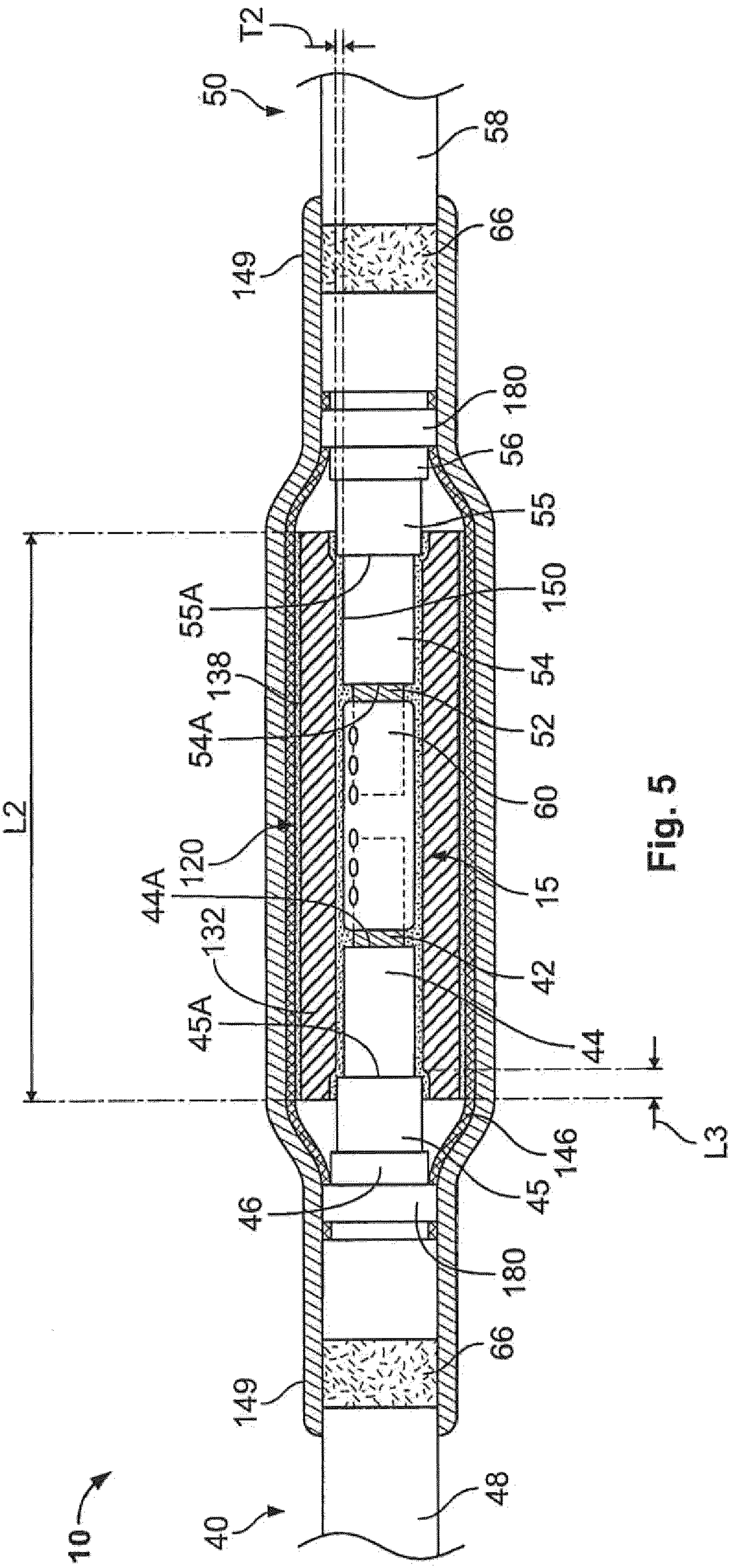
T2
50
58
66
149
180
56
55
55A
150
138
54
54A
52
60
L2
120
15
44A
132
42
45A
44
L3
146
45
46
180
66
149
48
40
10

Fig. 5

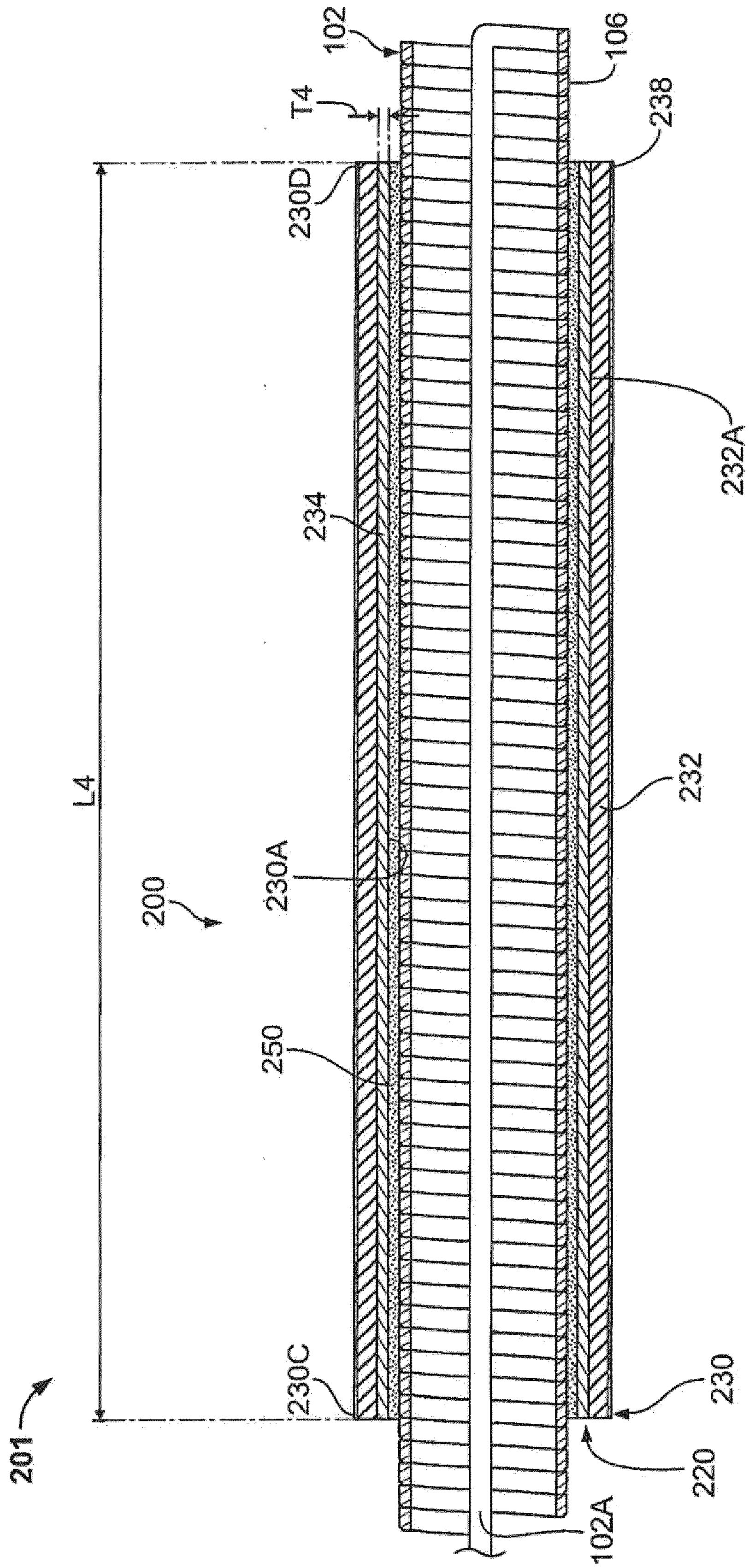
102
106
T4
238
230D
232A
234
232
230A
200
L4
250
230C
230
220
102A
201

Fig. 6

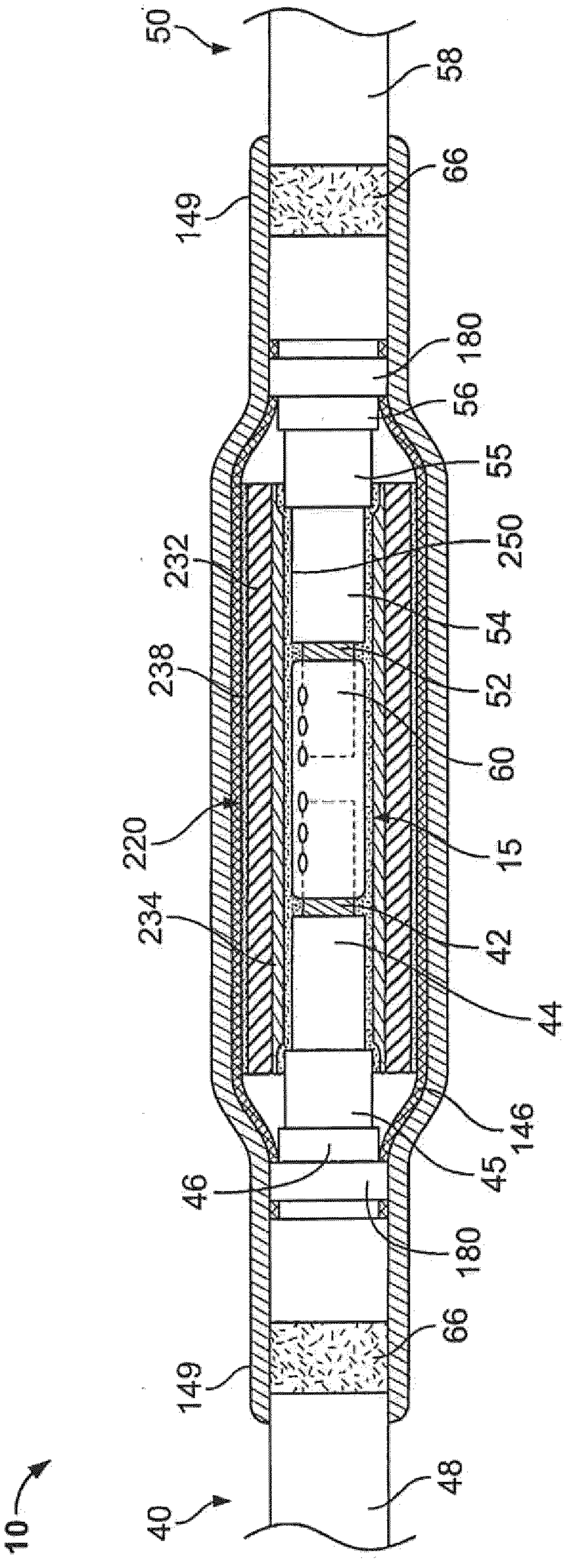
50
58
66
149
180
56
55
250
232
54
238
52
60
220
15
234
42
44
146
45
46
180
66
149
48
40
10

Fig. 7

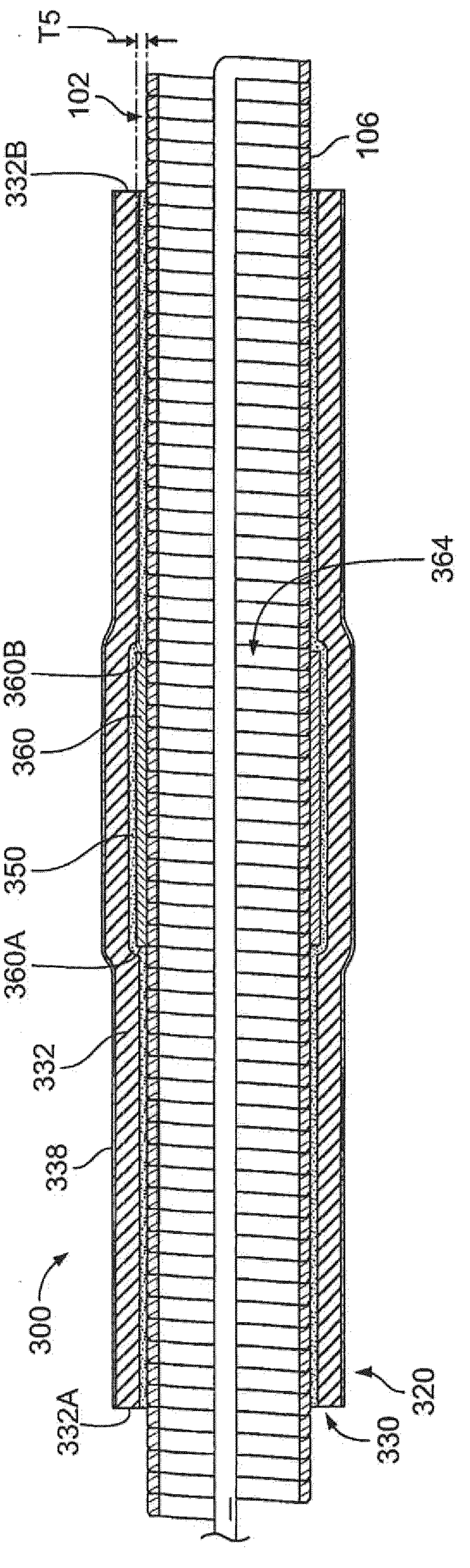

Fig. 8

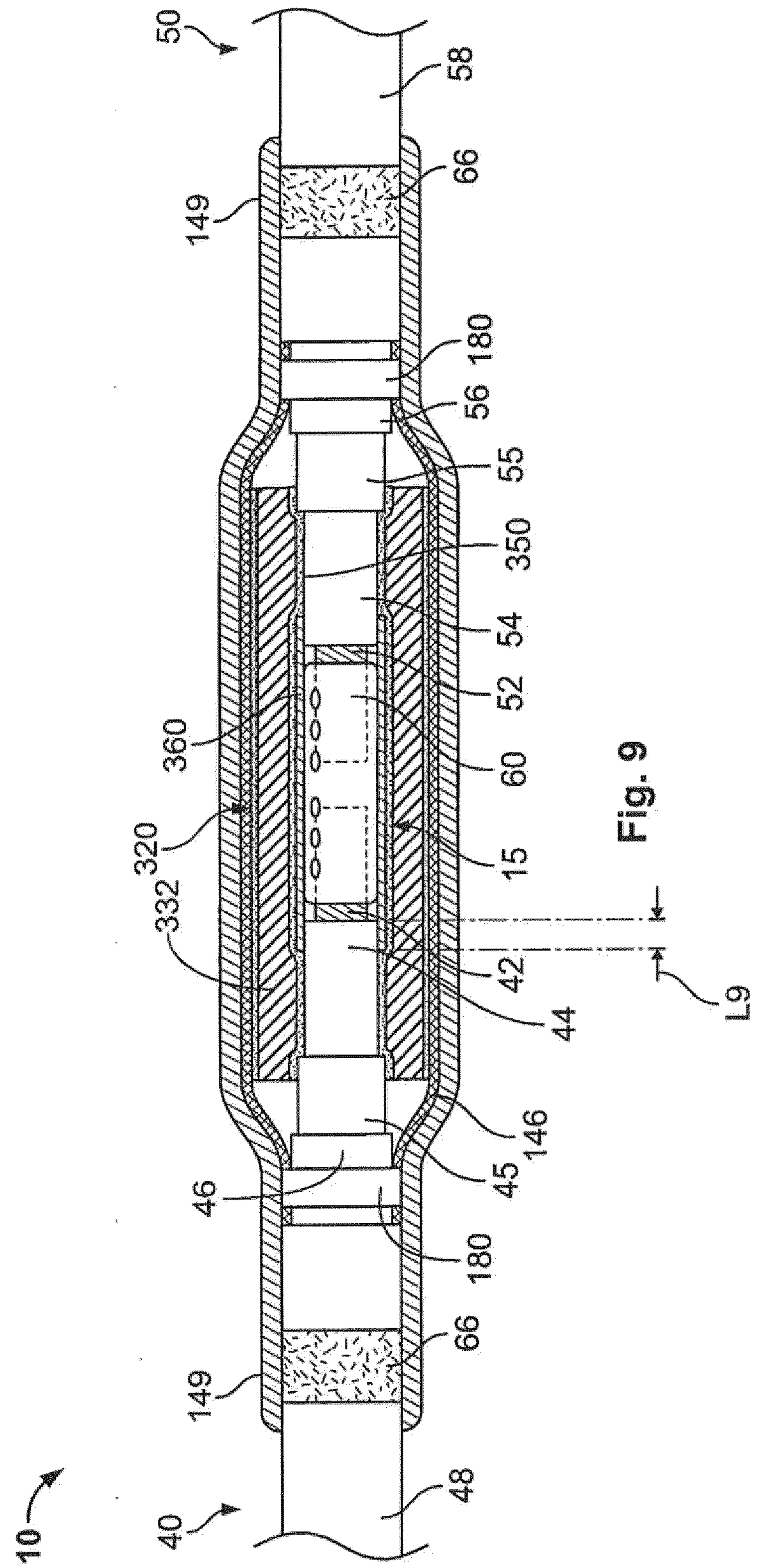
50
58
66
149
180
56
55
350
54
52
360
60
320
15
332
42
L9
44
146
45
46
180
66
149
48
40
10

Fig. 9

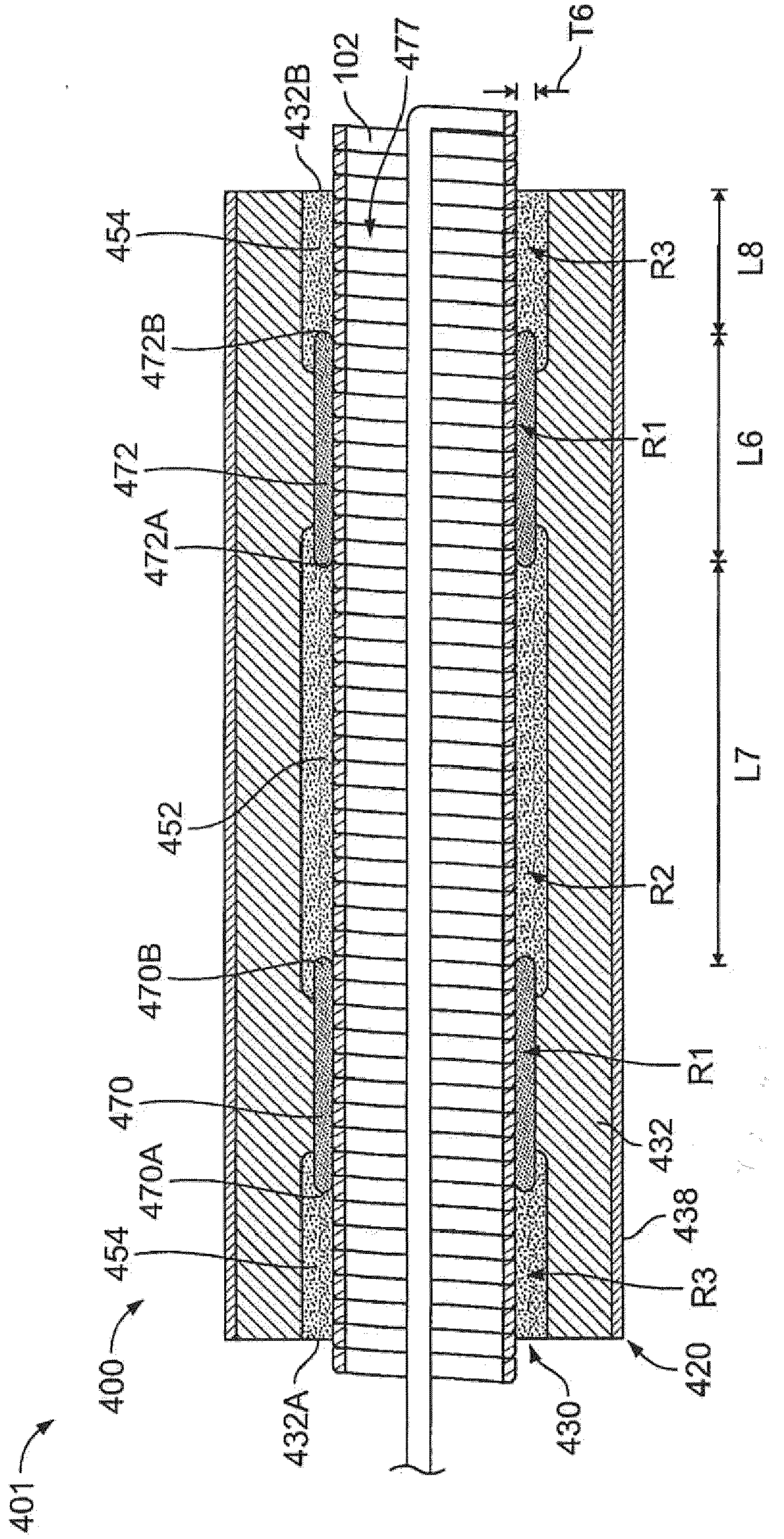
401
400
432A
454
470A
470
470B
452
472A
472
472B
454
432B
102
477
T6
R3
R1
R2
R1
R3
L8
L6
L7
432
438
430
420

Fig. 10

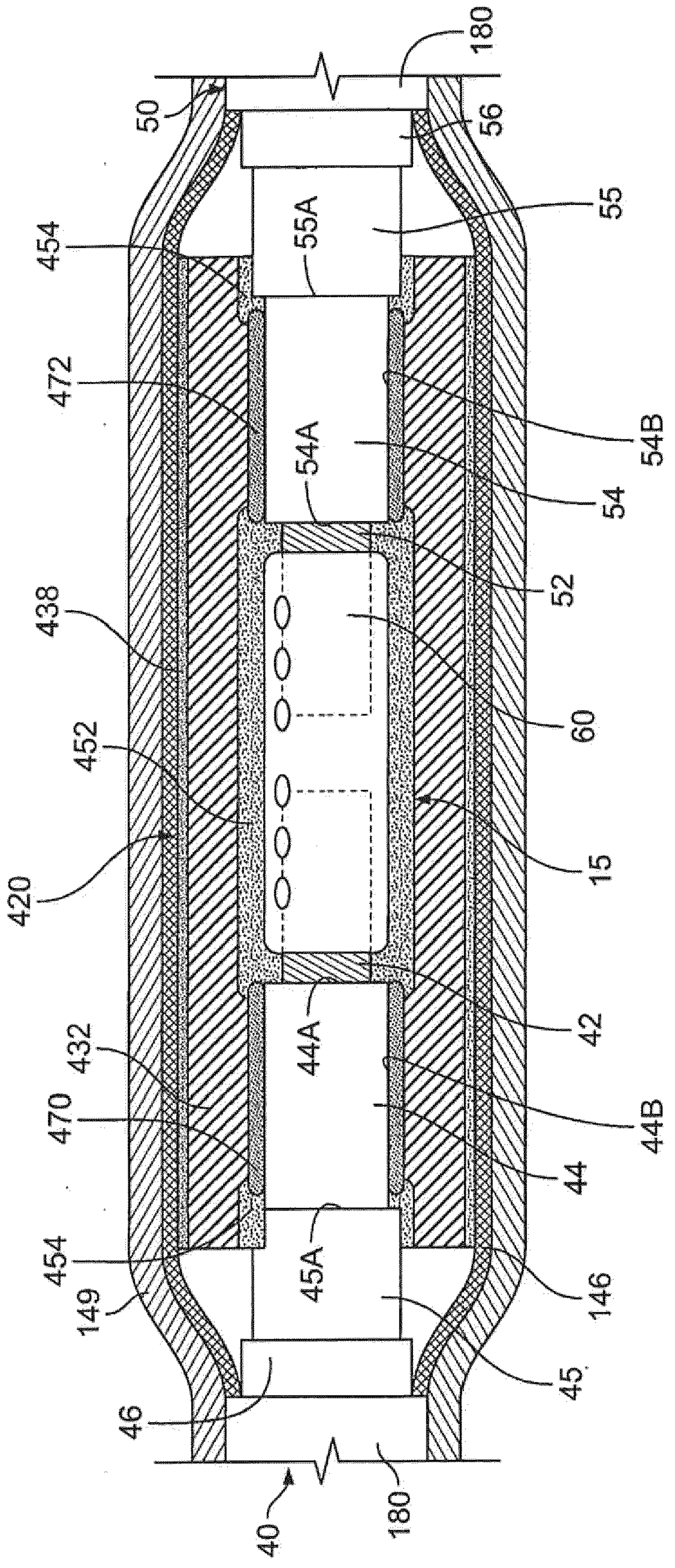
180
50
56
55
55A
454
472
54A
54B
54
52
438
60
452
15
420
42
44A
432
44B
470
44
45A
454
149
146
45
46
180
40

Fig. 11

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 16 8939

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CHEENNE-ASTORINO A ET AL: "Cold shrinkable technology for medium voltage cable accessory", TRANSMISSION AND DISTRIBUTION CONFERENCE, 1996. PROCEEDINGS., 1996 IEE E LOS ANGELES, CA, USA 15-20 SEPT. 1996, NEW YORK, NY, USA,IEEE, US, 15 September 1996 (1996-09-15), pages 384-390, XP010195374, DOI: 10.1109/TDC.1996.545964 ISBN: 978-0-7803-3522-6 * the whole document * -----	1-4,6-15	INV. H02G15/18 H02G15/188
X	US 6 015 629 A (HEYER THOMAS J D [US] ET AL) 18 January 2000 (2000-01-18) * column 3, line 21 - column 5, line 51; figures 1,2 * -----	1,2,4-15	
A	US 2014/262500 A1 (YAWORSKI HARRY GEORGE [US]) 18 September 2014 (2014-09-18) * paragraphs [0021] - [0055], [0063] - [0083]; figures 1-6 * -----	1-15	TECHNICAL FIELDS SEARCHED (IPC)
A	US 2010/132976 A1 (TOGNALI STEPHANE [FR] ET AL) 3 June 2010 (2010-06-03) * the whole document * -----	1-15	H02G

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 July 2023	Hermann, Robert

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 16 8939

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-07-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6015629 A	18-01-2000	AU 5319199 A	27-03-2000
		TW 434573 B	16-05-2001
		US 6015629 A	18-01-2000
		WO 0014840 A1	16-03-2000
US 2014262500 A1	18-09-2014	AU 2014241059 A1	01-10-2015
		BR 112015022326 A2	18-07-2017
		CA 2905245 A1	02-10-2014
		CN 105229881 A	06-01-2016
		EP 2973913 A1	20-01-2016
		ES 2933556 T3	10-02-2023
		MX 353320 B	08-01-2018
		PE 20160095 A1	03-03-2016
		PE 20201262 A1	19-11-2020
		US 2014262500 A1	18-09-2014
		US 2016329695 A1	10-11-2016
		WO 2014159228 A1	02-10-2014
US 2010132976 A1	03-06-2010	AR 066688 A1	09-09-2009
		AU 2008206985 A1	24-07-2008
		BR PI0806579 A2	06-05-2014
		CA 2675610 A1	24-07-2008
		CN 101606297 A	16-12-2009
		DK 2104973 T3	14-06-2018
		EP 2104973 A1	30-09-2009
		ES 2671894 T3	11-06-2018
		FR 2911441 A1	18-07-2008
		MY 149075 A	15-07-2013
		NO 2104973 T3	04-08-2018
		NZ 578098 A	29-06-2012
		US 2010132976 A1	03-06-2010
		WO 2008087151 A1	24-07-2008

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82